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6 IMPROVEMENTS IN CB PROTECTIVE CLOTHING

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INTRODUCTION

Chemical Protective Clothing, as it exists today in the US Army, has a number of unique features. It is a clothing system utilizing a variety of materials, including textiles, polymeric foam, unsupported films, elastomers and coated fabrics. These materials make up the current handwear, footwear, overgarment and headgear. The Chemical Biological Protective Mask is currently being studied and a significant effort is under way at the Chemical Systems Laboratory, ARRADCOM, to improve this item. For the purposes of this paper, the protective mask will not be discussed further except to recognize it as a component of the entire CB clothing system, its main role being to defeat chemical warfare agents that can enter through the auro-nasal route. Obviously, it also protects the face and eyes as well. The remainder of the CB protective clothing system is designed to protect against toxic or corrosive chemical warfare agents capable of affecting or penetrating through the skin. These latter agents are known as percutaneous agents and can cause casualties quickly at very low levels of concentration.

There are several guid'ng parameters in devising CB protective clothing that, in total, allow the scientist to focus on the problem rather quickly.

First of all, there are three basic mechanisms that can be utilized to design clothing that will intercept chemical agents and prevent them from coming in contact with the skin. A material can be selected that will provide a complete barrier to the agent, a

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piece overgarment composed of a nylon/cotton outer fabric and a polyurethane foam layer impregnated with activated carbon backed with nylon. This new system of clothing provides complete protection against all percutaneous and blistering chemical agents for long periods of time, when worn as directed.



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Fig 1. COMPLETE CHEMICAL PROTECTIVE OUTFIT

Since adoption of these items, NARADCOM has embarked on a series of research and development efforts to improve the overall properties of the clothing components while the Chemical Systems Laboratory, ARRAE OM, has continuing efforts ongoing to develop an improved respirator. The NARADCOM effort discussed in this paper presents some of the results of this research and development effort.

RESULTS AND DISCUSSION

1. Improved Flame/Thermal Resistant Overgarment

The new CB overgarment and the other components are all composed of organic materials that sustain combustion once ignited, and, indeed, even when removed from the flame environment, continue to burn to the point of total consumption. (Table I and Figure 2) It was recognized that certain military occupation specialties (MOS's) are exposed to flame/thermal flux intensities more often or more likely than others, particularly combat vehicle crewmen, helicopter pilots, tankers and the like.

TABLE I

FLAME TESTS ON CHEMICALLY PROTECTIVE OVERGARMENT MATERIALS

<u>Fabric System</u>	<u>Flame Resistance</u> <u>Method 5903</u>			<u>Flame Resistance</u> <u>Method 5905</u>	
	<u>AF(sec)</u>	<u>AG(sec)</u>	<u>CL(in)</u>	<u>AF(sec)</u>	<u>(% Consumed)</u>
Standard Foam/ Nylon Tricot Laminate	44	*	6.5	**	100
Ideal Garment (Goal)	0	0	3.0	0	20

*Sparking occurs during afterflaming but glowing stops when flaming stops

**Consumed during test so no afterflame measured

The standard overgarment was placed on several mannikins and exposed to the fire pit test. The uniform caught fire almost immediately and continued to flame after removal from the flame source. The flames had to be extinguished or the garment would have continued to burn. When the garment was re-examined at that time, the uniform was mostly destroyed. In addition, the mannikins were equipped with sensors capable of measuring both the heat flux and the temperatures reached. These measurements showed that if the mannikin had been a soldier dressed in the overgarment and exposed to such a heat flux, second and third degree burns could have been expected. The experiment was repeated several times. Both the results mentioned and the flaming as shown in Figure 2 were typical in every case.



Fig 2. STANDARD OVERGARMENT 8 SECONDS AFTER FIRE PIT EXPOSURE

A product improvement effort was therefore initiated at NARADCOM to attempt to make the overgarment, at the very least, flame-resistant, and hopefully, flameproof. A number of approaches were attempted and the most successful approach selected as a modification to be considered for an improved item to be adopted in 1981.

The concept we have utilized is one never before successfully utilized in clothing. The principle is called "Intumescence." Our experiments have shown that utilizing this principle, slightly modified, a flame-resistant overgarment system can be developed which offers excellent flame/thermal protection.

The basic principle of "Intumescence" is the formation of a protective foam upon the application of a high thermal flux or flame source. The foam provides a thermal insulative barrier against the transfer of heat to the object. Intumescent paints have been used

for a number of years to protect surfaces of wood and metal in a variety of applications.

Basically, an intumescent formulation is composed of three descriptive components, a chemical that can be thermally decomposed to a strong dehydrating acid which once formed, dehydrates a second chemical quickly to copious quantities of carbon particulates. A third chemical is usually present that liberates gases at an appropriate temperature to foam the newly formed carbon particles.

In our case, with the overgarment foam, we were able to do away with the latter foaming component since we were already dealing with a foam item. Therefore, all that was needed was the dehydrating acid-forming chemical and a chemical readily dehydratable to carbon. Formulation experiments with this system finally resulted in the best combination of a commercial ammonium polyphosphate, tripentaerythritol and an acrylic binder to hold the chemicals in place in the foam.

In addition, the nylon-cotton outer fabric which could pose a flame and melt drip hazard was replaced with a flame-resistant Nomex III. Finally, the nylon support backing material which also was a hazard was replaced by a lightweight cotton fabric. During the processing of the intumescent foam, which contains the backing fabric for strength, the cotton fibers absorb sufficient intumescent chemicals rendering it also, flame/thermal resistant. Figure 3 shows the comparison between the standard and flame-resistant modified overgarment.

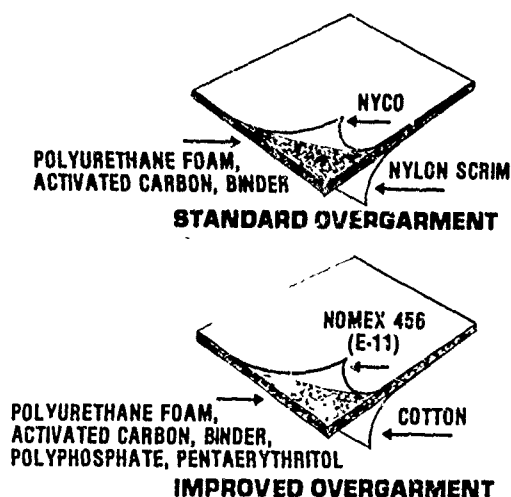


Fig 3. COMPARISON OF STANDARD AND FLAME RESISTANT OVERGARMENTS

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The laboratory testing of the improved overgarment showed that the goals listed in Table I were met or exceeded. Uniforms were made of the new material, placed on instrumented mannikins and exposed to fire pit testing. In the fire pit, the overgarment survived a 1200°F fire completely intact. (Figure 4) The sensors on the mannikin indicated that the mannikin had received no second or third degree burns whatsoever.

Chemical agent protective qualities are not seriously degraded by this intumescent formulation. In fact, the same system exposed to the fire pit test provided over 24 hours protection when tested against both mustard gas and a nerve agent (GB).

Another approach which could be considered to improve the overgarment would be to make the foam thinner. In this way, the comfort factor could be enhanced and from a design point of view, alternate configurations could be considered such as CB protective liners instead of overgarments. The limitation of this approach is a mechanical one; commercial production equipment is not likely to be able to cut foam thickness less than .050 in. thick, at least with the reproducibility and consistency required for these kind of materials.

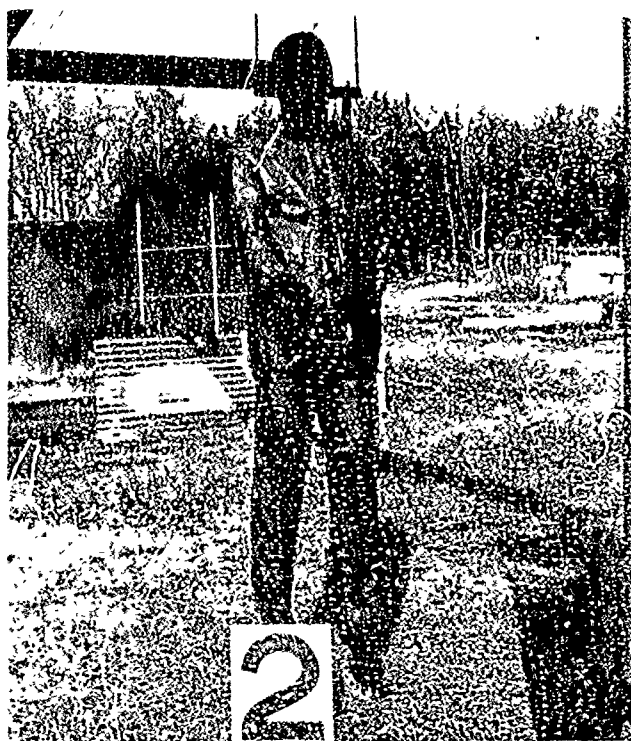


Fig 4. FLAME HARDENED PROTECTIVE GARMENT AFTER FIRE PIT EXPOSURE

Foam thicknesses of .050 in. have been prepared, impregnated with activated carbon and are currently being evaluated. Another alternative currently being explored is the possibility of spraying the foam directly onto the fabric in which case very thin foam thicknesses can be achieved. A considerable amount of work has yet to be done before decisions can be made as to whether this approach has practical merit.

2. Chemical Agent Protective Textile Materials

If one were able to develop a chemical agent protective activated carbon-based textile system, it would have merit for many reasons. Such a system could provide increased drape, comfort and possibly could be laundered and regenerated. Because it would not have its activity lowered by the presence of binders or flame bonding, longer chemical agent protective lifetimes could be anticipated. Longer lifetime in storage could be realized resulting in considerable savings.

Four possibilities exist whereby one could transition activated carbon into textile fibrous systems. Figure 5 illustrates these possibilities.

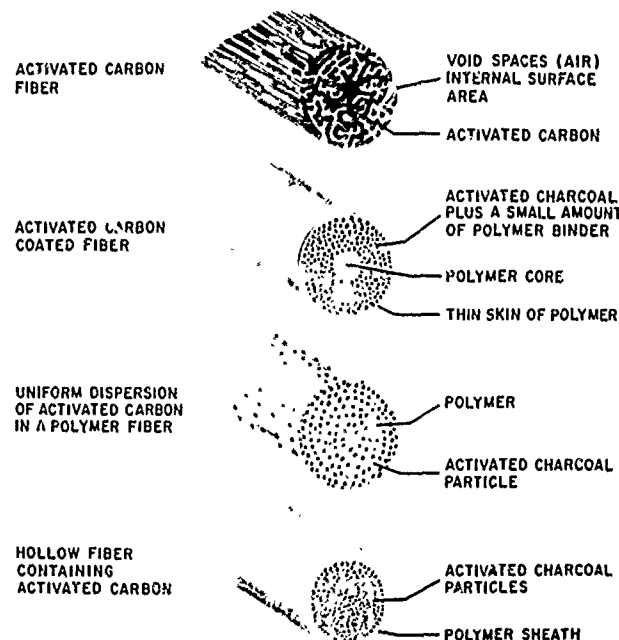


Fig 5. ACTIVE CARBON FIBER TYPES

a. Activated Carbon Fibrous Systems

Pure activated carbon fibers can be made by several different processes which will not be discussed in this paper. Probably the largest single disadvantage of activated carbon fibers is the brittle nature of these fibers and their lack of strength. One way to overcome these deficiencies is to wrap or braid the carbon yarns with another fiber to give the resulting composite fiber, flexibility and strength. Both fibers of this type and fabric have been made using this approach. Figure 6 shows a fabric made of a cotton-wrapped activated carbon yarn and then knitted into a fabric with Nomex.

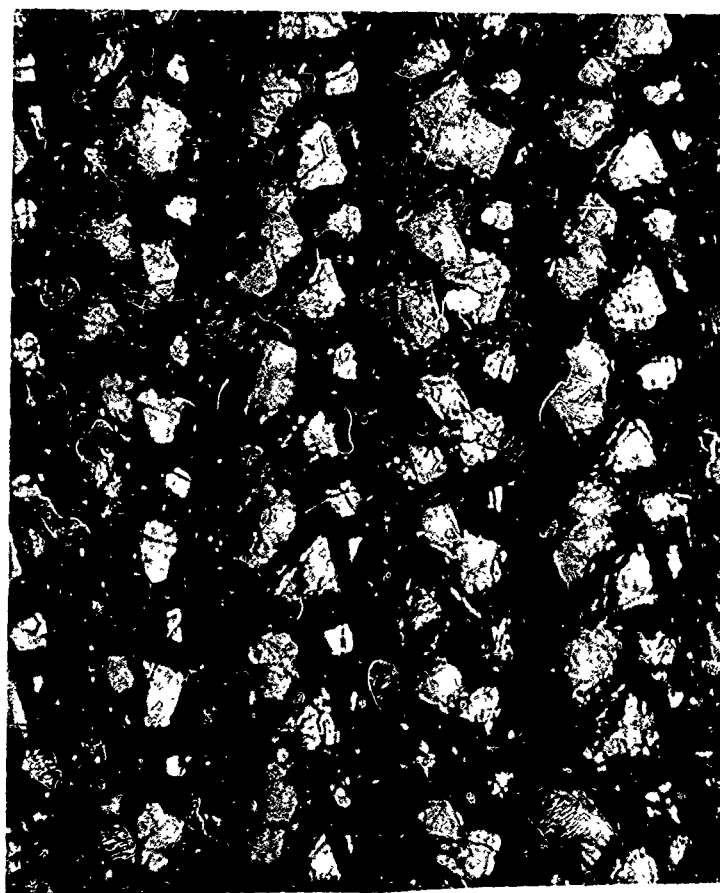


Fig 6. COTTON WRAPPED ACTIVE CARBON YARN IN A KNITTED STRUCTURE

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Experimental uniforms of these fabrics have been fabricated and evaluated from a comfort point of view with results indicating improvements over the standard foam overgarment. These same uniforms have been worn in troop trials over obstacle courses and the report from these tests indicates a high degree of acceptance.

Another approach is the concept of activated carbon fabrics. In this case, we select a precursor already woven which by judicious selection of temperature and gaseous environments can be converted to a fabric with high sorption capacity and adequate strength. Because no binder is present, the activity of the active carbon fabric is all retained. The precursors which have been actively considered for the preparation of active carbon fabrics are acrylic, rayon and polyacrylonitrile (PAN) fabrics. Of these, the polyacrylonitrile has the advantage of providing a greater yield of end products than do the other two. At NARADCOM, experimentation is being conducted on carbon fabrics prepared from both rayon and PAN fabrics, but we have an active interest in a third precursor, pitch. Work to date on pitch fabrics has shown that very high yields are possible along with considerable activity and moderate strength. This work is continuing to optimize the process and to produce the fabric quickly and cheaply on existing equipment. This could result in a completely domestic source of active carbon fabric.

b. Hollow Core Activated Carbon-Filled Fibers

A second approach wherein one could enter the field of activated carbon-based textile systems is one where activated carbon particles are contained in a microporous hollow fiber. The potential advantage in this concept is that one would have basically a textile material or fabric that would serve as a chemical agent protective assembly when these chemical agents were present. At all other times, it would function as a standard fabric offering the wearer the advantages of any textile system.

For illustrative purposes, a scanning electron microscope photograph of a hollow fiber filled with particulate activated carbon is shown in Figure 7. This is a cross-section of the as-spun fiber 200 microns in diameter which after drawing will be reduced to 75 - 100 microns. This latter dimension is well in the range of practical textile fibers.

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Fig 7. CROSS SECTION OF HOLLOW FIBER

One of the most interesting aspects of this work involved making the shell of the hollow fiber porous so that the agent would pass through that shell and be sorbed in the active carbon. In the initial studies, combinations of polypropylene and wax were spun into fibers. After the fibers filled with carbon were drawn, the wax was extracted to produce pores. These pores were too small for rapid permeation of vapors. Subsequent studies showed that a combination of polypropylene, a low molecular weight polyethylene and wax produced the proper crystalline morphology.

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In Figure 8, the scanning electron micrograph shows a spherulitic crystal structure separated by extended chain crystals.

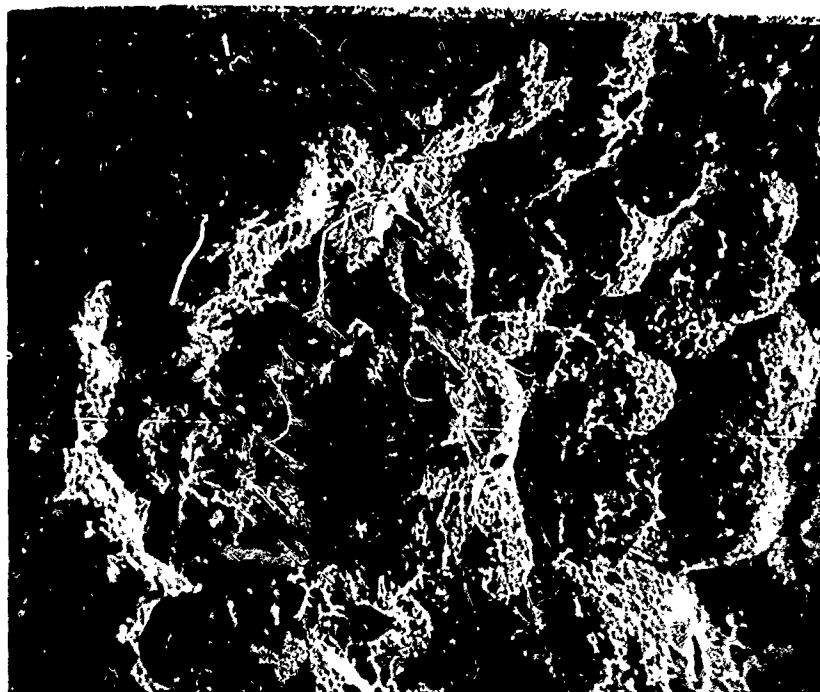


Fig 8. MICROSTRUCTURE OF HOLLOW FIBER WALL (3000X)

Pores capable of high permeation rates are available both between spherulites and as shown in the photograph within the spherulite itself. Fabrics have been woven of these fibers which for all practical purposes have the feel and appearance of a regular fabric.

In conclusion, a variety of approaches are being considered for the continued development of improved chemical agent protective clothing systems. The development of enhanced protection via improved activated carbon systems is leading the procession of new material configurations followed by a number of alternate routes any of which could alter the picture of what materials will be used in future generations of Chemical Protective Clothing.

As expected, laboratory measurements of the sorptive capabilities of the active carbon in these textile forms is high. Research and development efforts are continuing to ascertain the limitations, advantages and disadvantages of these approaches. Overall we expect the advantages will far outweigh the disadvantages.

3. CB Protection for the Extremities

Thus far, little has been said about the butyl rubber components of the current chemical protective clothing.

Experiments to develop improved elastomers are under way. The need for enhanced chemical agent protection, enhanced flexibility, and physical tactility are properties that are being emphasized. However, we must also consider the desirability of countering disadvantages such as the flammability and the marked tendency of butyl to swell in petroleum solvents. One avenue of research has been the exploitation of a novel rubber called phosphazene. This family of elastomers, based upon the backbone of phosphorous and nitrogen and containing side groups has unusual properties. These properties include a high degree of flame resistance, good low temperature flexibility and good resistance to swelling in petroleum solvents. The resistance to chemical agents is good and can be enhanced by compounding and curing variations. This work is currently under way at NARADCOM and has had an additional spinoff. Some of the compounding ingredients and methods which enhanced the chemical protective qualities of phosphazene rubber appear also to have beneficial results when applied to commercial elastomers.

SUMMARY

---^{all} Generally, three areas of active research have been identified, in this paper. The first is the flame hardening of the overgarment which is proceeding with high success and an objective of implementation by 1981. The second area discussed involved the various methods of utilizing a sorptive material such as active carbon. These approaches such as active carbon fibers, active carbon fabrics, and

hollow fibers are still in an experimental stage. The third area, protection of the extremities, has produced some very interesting results but needs more work to reduce the concepts to reality in terms of availability and cost. These three areas were chosen because of the progress made in each area and because they hold the prospect of high success potential.

Other approaches have been and are being considered. They include the use of reactive groups alone or combined with sorption. The XXCC₃ impregnated garment long in the Army system utilized a chloramide to react with the mustard gas and V-type nerve agents, while chlorinated paraffin sorbed the G-agent. We would anticipate that future combinations would be based upon the insertion of appropriate functional groups on a sorbent material like carbon or a fibrous material. The problem is that a particular functional group may be fine for one agent and poor for another. Antagonistic functional groups on the same substrate might be unstable.

A second approach could utilize membranes in their broadest sense. The membranes would have to be barriers against the larger molecules typical of the chemical agents while allowing passage of air or better still, moisture. Some types of membranes may encourage the passage of water vapor while discouraging the passage of other molecules. We are considering these latter approaches but realize the difficulty in producing durable garments with universal chemical protection from these perhaps more novel techniques.